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Insect Eggs . . . . . *J. W. L. Beament* 139

Fertilizer Placement . . . . . *F. V. Widdowson* 147

An Advisory Project on Barley Manuring *A. R. Staniforth* 151

Blood Groups and Poultry Breeding . . *D. G. Gilmour* 156

Farm Management Group Meetings in Cornwall . . *R. S. Boyer* 161

Chemical Weed Control and Grassland . *Lewis Jones* 166

The Economic Importance of Virus Diseases of Fruit Trees in England . . . *A. F. Posnette* 170

Formulae for Average Sunshine Values . *L. P. Smith* 175

REGIONAL NOTE

An Exercise in Evaluation . . . . *T. J. Legowski* 179

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Insect Eggs

J. W. L. BEAMENT

A.R.C. Unit of Insect Physiology, University of Cambridge

THE LIFE CYCLE of an insect follows a typical pattern. After emerging from the egg in one of a variety of forms such as caterpillar, maggot, hopper, or grub, the young insect grows and eventually turns into the winged adult; this mates and lays eggs to start the next cycle. They are susceptible to control at any stage, but there are real advantages in killing the egg.

Insects frequently overwinter as eggs, so that a poison may be applied when plants are least sensitive to damage, when there is no risk of contaminating crops, and when labour can most easily be spared. Because any insecticide may kill a useful insect as well as a pest, the winter ovicide may offer particular possibilities of selective control. An egg is usually fixed to some surface, and it cannot therefore escape or be disturbed by the process of applying a poison. Most important of all, by killing an egg one can prevent problems from occurring, for it is the active stages and not the egg which cause damage.

Trial-and-Error Selection of Insecticides

Insecticides, including those specifically chosen to kill eggs—ovicides—have evolved almost entirely through trial-and-error selection. This is no condemnation of their originators, but another way of putting our present state of knowledge. We are so far from understanding all the details of the chemical processes which go on in living things, and unable to explain precisely how particular poisons do interfere with those mechanisms to cause death, that it is not practical to attempt to formulate an insecticide from first principles. But this does not mean that there is no point in trying to discover more about the way in which existing materials work. One may find that a particular chemical substance is very toxic to insects from a simple empirical experiment on a few insects by one or two laboratory workers. But to discover, by trial and error, the best mode of application, dose, formulation, time of application and so on in field experiments is obviously so expensive and prolonged that any indications or basic principles which pure research can provide are very worth while.

Methods by which Poisons Penetrate

The process of killing an insect with an insecticide can generally be divided into three: getting the poison on to the animal, getting it into the animal, and what happens when it gets there. The problem of formulation can be narrowed if, for example, we know something about the structures through which the poison must penetrate. For a gas, or vapour, we become interested in the insect's respiratory system: we

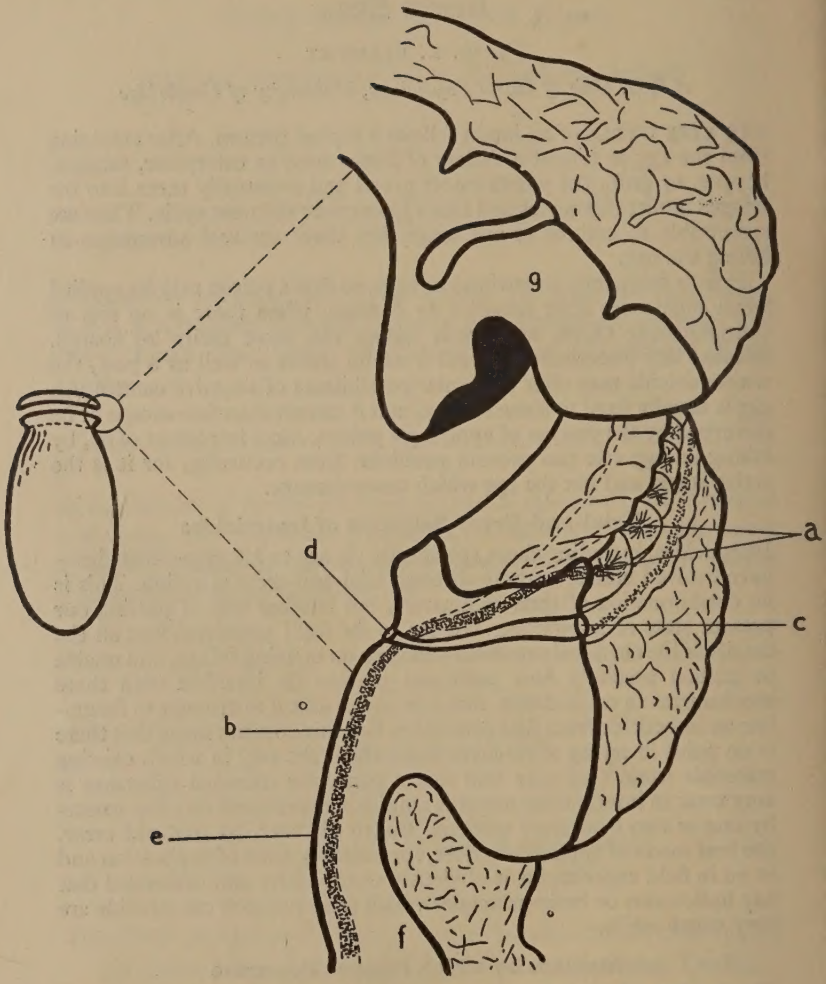

Fig. 1. An enlarged section of an insect egg, with its cap (used for emergence) displaced.

a. respiratory openings; b. respiratory sponge; c. outer opening of micropyle; d. inner opening of micropyle; e. waterproofing wax layer; f. lipoprotein main barrier of the shell; g. lipoprotein main barrier of the cap.

consider the gut and digestive processes in relation to a stomach poison, while the commonest of all insecticides—the contact poison—must pass through the animal's skin.

The A.R.C. Unit at Cambridge, under the leadership of Professor Wigglesworth, has obtained an enormous amount of information about the skin of the active stages of insects. This is an almost unique animal structure; from it, the whole of the sense organs, mouthparts and gut linings, breathing organs, legs, wings, and entire skeleton are formed. These are of such interest academically that little further excuse need be sought for studying them. However, particular parts of the skin may provide ready access to materials with the right properties of wetting, solubility and so on. Basic suggestions can be made about the physico-chemical properties which each kind of insecticide must have, in order to gain access to the living substance inside the skin.

Structure and Function of the Insect Egg Shell

The insect egg shell is no less a protection to its living contents, but for obvious reasons our knowledge of it has, until recently, been almost non-existent. The embryologist who is concerned with that living content, has long avoided the insect egg, for its tough, brittle shell is proverbially known amongst biologists as one of the most awkward materials to handle. Yet an ovicide must pass through the shell to poison the egg, or it must interfere with some part of the shell vital to its contents. To fill this gap in knowledge, a programme of investigation into the structure and function of the insect egg shell was started by the A.R.C. Unit in the immediate post-war period.

The shell structure proves to be surprisingly complex. When the egg is laid the shell may comprise as many as eight chemically different concentric layers built into curious sculpturings and so on[1] (see Fig. 1). There may be specialized regions, such as pre-formed trap-doors, sprung lids or zip-fasteners to allow easy emergence at the end of the developmental period[2] (see Fig. 2).

A most efficient Poison Barrier

Compared with the relatively uniform plan on which insect skin is built up, egg shells have a far greater variety of forms and construction, but certain properties are regularly found. One of the commonest constituents of egg shells is the substance "chorionin" which is a chemical compound of oil and protein. It is exceedingly resistant to chemical attack, and only such a process as heating it in fuming nitric acid saturated with potassium chlorate will break it down—which can be quite an exciting experiment to perform! Chorionin proves to be virtually impermeable to almost every sort of liquid material, except water, and also to most gases. It must be one of the most efficient poison barriers which Nature has ever contrived.

Water is very critical to the development of an egg. Unlike an insect

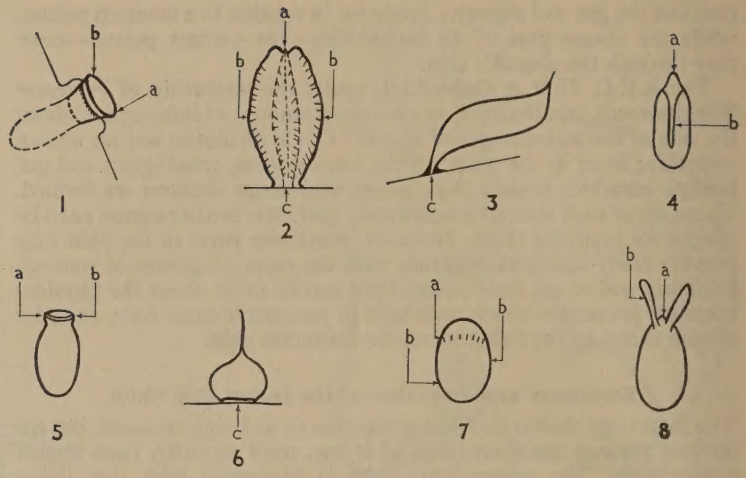

Fig. 2. A variety of insect eggs.

1. a capsid egg inserted into plant tissue; 2. a butterfly egg on a leaf; 3. egg of apple-sucker on plant; 4. blow-fly egg; 5. a bug egg; 6. egg of red spider mite; 7. beetle egg; 8. fruit-fly egg. NOT TO SCALE. a. micropyles; b. respiratory openings; c. other sites of poison entry.

in an active stage, an egg has generally no means of replenishing its supply, so it must conserve what water it has to the uttermost. For this purpose, a typical egg has, on the inner surface of its shell, a thin layer of paraffinic wax[3] (see Fig. 1). Because of a special molecular arrangement, this wax has quite spectacular waterproofing properties. To lose a pint of water through a square inch of shell into dry air would take an egg 90 years; but to overwinter without drying up, a minute egg must have this kind of protection. Thus, in addition to the chorionin, the wax will certainly be as efficient a barrier to the inward passage of water-soluble poisons as could be imagined.

Chinks in the Armour

It might appear that the living egg has been provided with the perfect defence against chemical control; there are, however, two biological functions which provide the chink in the armour. A great many eggs are actually fertilized after the shell has been secreted round them in the ovary, and a canal or "micropyle" passes right through the shell, in order to allow the passage of the sperm[2] (see Figs. 1, and 2). Secondly, like all other living material, the egg must breathe. An egg shell, as so far described, is much too impermeable to oxygen to allow a fraction of the necessary (or indeed the measured) respiration rate to take place. This contradiction led to the discovery of respiratory pores on the surface

of the egg shell. But a series of canals leading from these pores to the outer surface of the wax layer are not sufficient—these pores lead into a minutely fine sponge (Fig. 1) which encloses the egg immediately outside the wax.[4] Oxygen can thus diffuse throughout the sponge, and across the whole area of the wax.

Entry of Water

When laying an egg, the mother very often sticks the egg to a surface with a cement, which may cover the rest of the egg's surface and the openings of these respiratory tubes. But when this cement "sets", it breaks up into a fine sponge, which allows air to pass through it freely.[4] If an egg is temporarily submerged in water, as it may well be naturally during rain, all these openings will be cut off from the air. Most eggs can survive such immersion at least for some hours: that is, until the water dries up again. Furthermore, the respiratory tubes and sponges are not immediately filled with such water—their surfaces are water-repellant and it may take an hour or more for a detectable amount of water to enter a tube, let alone get into the inner sponge. By following the path of solutions of water-soluble poisons, also containing a dye, it is found that such an egg can be submerged for perhaps half-an-hour[5] before this kind of poison reaches the spongy layer. If the egg is then allowed to dry, no toxic effect occurs at all; as the solution progresses through the spongy layer, so the toxic effect appears and increases.

Wetting Agents

It is obvious that a spray droplet of such a material must not merely hit an egg, but must land on a respiratory opening, *and* remain there without drying up for long enough to pass down the tube and sufficiently into the sponge, if it is to be successful. If a wetting agent or detergent is included in such a solution of poison, it may greatly increase the speed and efficiency with which the process of getting into the spongy layer is effected, and hence the degree of control obtained. The role of this sponge does not however end there. If the water of the solution happens to dry up before enough poison has penetrated through the wax, a deposit of poison and perhaps detergent, harmless enough, may line the respiratory tubes and part of the sponge. Any further rain on this egg may lead to the re-formation of a toxic solution and which in effect is another spray treatment. Such a phenomenon may be particularly important. Both the living material and also the membranes surrounding it within the shell proper change in their resistance during development, and the egg may be much easier to kill at some time later than when it is initially sprayed.

Penetration by Oil

By contrast, the natural water-repelling qualities of the egg shell surface and of the spongy material automatically means that it is readily

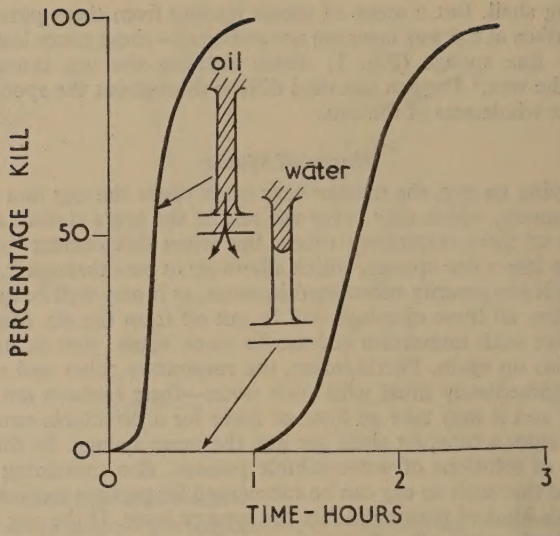

Fig. 3. Oily poisonous solutions wet the pores of the shell: kill results from very short immersions. Aqueous solutions take up to 1 hour before they reach the bottom of the pores, and have any toxic action.

wetted by oily liquids (See Fig. 3). The respiratory openings and sponge will fill with an oil in a matter of seconds. This explains why one of the earliest of ovicidal materials—the winter petroleum—is so effective, despite the fact that a light petroleum would not be considered at all toxic to living material. Not only does such an oil prevent the diffusion of air, but as it is hardly volatile, it does not dry out from the shell before the developing embryo has been suffocated. Equally well, an oil is a good solvent for wax, so that if an oil-based solution of poison runs down one of the fertilization canals, it comes directly into contact with the wax layer at its end, and can pass readily into the living material.[5] This would seem to be the obvious answer to penetration, were it not for the layers which the developing egg may produce itself inside the wax which lines its shell.

Susceptibility of Eggs in early Life

Not unnaturally, at the moment of fertilization, the living substance must lie against the inner end of the micropyles, separated only by the thin sheet of wax. There is some evidence[3] that the sperm secretes an emulsifier to assist it through the wax. At the start of its independent life, the egg has only its shell and wax as protection, and all evidence points to the fact that eggs are easiest to kill while they are freshly laid. Within a day, however, a membrane is laid down inside the wax (Fig. 3)

Eggs of the bug *Rhodnius* on which the first detailed work on an insect egg shell was carried out.

Eggs of the fruit-fly *Drosophila*; two on right have intact shells; two on left have the outer shell removed and developing germ is visible through the transparent inner shell layer.

PLATE I

"Band" of eggs of the Lackey moth (Clissiocampa) on an apple twig.

Vacated egg shells of the Poplar Hawk moth on a piece of straw.

PLATE II

which is much less easily penetrated by oily materials than by water-soluble ones. The resistance of the egg to oil-soluble poisons rises rapidly, whereas to others it shows little change.

Some eggs may carry out further waterproofing by impregnating the membrane they have laid down with more wax. As a result of this, the resistance of the egg to water-soluble poisons rises sharply, but as this new wax may form a preferential path of entry to an oily material, resistance to this kind of poison falls.[6]

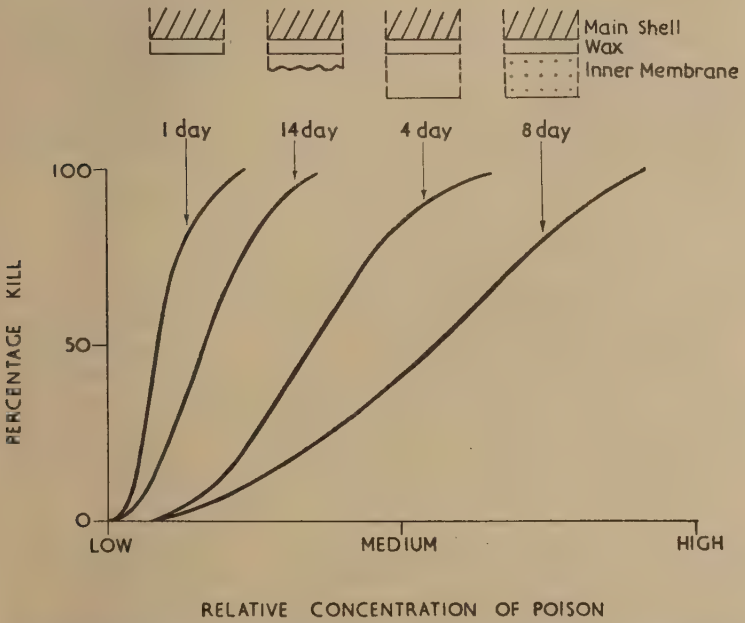

Fig. 4.The change in resistance of an egg taking 15 days to develop, due to the secretion of membranes inside the shell, their impregnation with wax (8 days) and re-solution before hatching (14 days).

This constitutes the state of affairs during the middle period of development, in which eggs most frequently become dormant to overwinter. In general terms, the egg is not only at its most resistant then, but also its rate of breathing may drop so low that even blocking up the respiratory tubes may not suffocate it.

Susceptibility prior to Emergence

Ultimately, the young insect has to hatch. This it may do in a variety of ways, for example, by cutting its way out with its mouthparts (perhaps

picking up a poison deposited on the surface of the shell, which had never penetrated at all). Many shells are far too strong, and the immature insect far too weak, to do more than operate one of the release mechanisms referred to above. Even to do this, it must get rid of the membrane it has itself secreted inside its shell. Two things may now occur. Just before it hatches, the young insect will have reduced its defence to a similar state as when the egg was laid, and accordingly be once again most vulnerable to any penetrating poison. This means not only that an actual spray application, but that a re-solution through rain of an existing deposit, may do the trick. It also means that any poison which has penetrated into but not *through* this inner membrane is not merely released but actually absorbed by the insect together with the break-down products of the membrane itself.[6] Together, these two processes probably largely account for the peculiar, but frequently reported phenomenon that an egg dies, not when it is sprayed, but days or even months afterwards, just before hatching.

Variations between Species

All these principles are generalizations about the sorts of thing which are likely to apply to an egg. But each species must be considered on its merits. Thus, many eggs, such as of capsid bugs, are inserted into plant tissues. They are without waterproofing wax, for they can draw water from the plant. The end of the egg which is exposed has its respiratory openings concentrated there, thus giving a point of access. Butterfly and moth eggs are stuck on to leaf surfaces by an oily cement[7] making such good contact that poisons may move systemically from the plant across and into the egg to kill it.[8]

One of the particularly serious problems when the A.R.C. Unit started this work was the red spider mite, and however little is known of insects and their eggs, we certainly know much less about mites. The egg of this mite is smaller in diameter than the thickness of the egg shell of the first bug egg which was investigated. However, by using the techniques and ideas developed on larger eggs, it was possible to resolve this minute shell into four layers, with a wax inside, and an exceptionally hard wax coating outside. It has also been possible to show differences between the summer and winter egg, both in their structure and in the timing of the formation of the barriers. Recent work shows that the region where the egg is attached to the leaf or bark is the probable site of poison entry.[9] When these eggs are laid one on top of another, in heavy winter infestations, the hard wax of one shell may seal the base of the egg laid on to it (Fig. 2) and so give a proportion of the population a quite phenomenal resistance to poisons.

Much remains to be discovered about the variety of eggs, even of the economically important insects alone, but these basic principles will certainly serve as a guide to future work.

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Fertilizer Placement

F. V. WIDDOWSON

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BROADCASTING is still the most common method of manuring; is it adequate or could higher yields be obtained from alternative methods? In 1959, farmers bought fertilizers worth more than £80,000,000; they obviously need to get the maximum possible return for the outlay and much experimental work has been done to find the most efficient way to use fertilizers.

Rapid and Full Benefit

The basis of an efficient method of manuring is to put the fertilizer where the crop can obtain rapid and full benefit, without damage to early growth. Broadcasting fulfils these requirements for established grassland,[8] but not for many arable crops, because nutrients distributed through the soil are not readily available to the roots of the young plants. The obvious alternative, placement in contact with the seed, is often unsatisfactory, especially for crops grown in wide rows, because drilling heavy doses of fertilizer with the seed may cause crop failure. Experiments showed, however, that heavy dressings of fertilizer could be

drilled with safety, provided seed and fertilizer were separated laterally by a narrow band of soil. Fertilizer applications placed to the side of the seed in this way were superior to broadcast dressings for many crops. Sideband placement has not yet been fully accepted in farm practice, possibly because it has been difficult to develop suitable machines, and because contact placement is often safe when crops are planted early in deep, moist seedbeds.

Experiments on several crops showed that higher yields were obtained from placed dressings of nitrogen, phosphate and potash than from equivalent broadcast dressing.[19] Gains from placing superphosphate and muriate of potash were greatest on soils containing little available phosphate or potash, and were least on richer soils. Small gains in yield from placing nitrogen were general.[20,21] Special placement methods may be difficult to justify on rich soils, unless field organization is also improved. It is often advantageous in practice to sow seed and fertilizer with one machine in one operation, and placement drills may often be justified for these reasons alone.

The following factors determine the best method of fertilizer application for the individual farmer:

The level of available nutrients in the soil.

The row-width of the crops and the practicability of sowing seed and fertilizer in one operation.

The acreage of crops being grown and the cost of special fertilizer machinery in relation to returns.

Combine-Drilling

More than 6,000,000 acres of arable land grew cereals in 1959, and these included large areas of poor soils where efficient methods of manuring are most needed. As cereals are grown in narrow rows and receive only moderate amounts of fertilizer, combine drills are commonly used to sow seed and fertilizer in one operation. Experiments with superphosphate, muriate of potash and sulphate of ammonia all showed that higher yields of wheat and barley were obtained by combine-drilling rather than broadcasting each of these fertilizers.[11,12,20,22] Germination was not damaged enough to affect yields at the levels of manuring needed for full yields.[17]

Combine drills should therefore be used to apply all the P and K for autumn cereals, plus part of the total nitrogen requirements, and to apply all the N, P and K needed by spring-sown cereals. In recent experiments, 0·6 cwt N/acre as ammonium sulphate plus basal P and K were combine-drilled safely with spring barley, but damage occurred when 0·9 cwt N/acre was drilled.[17] Tests with combine-drilled dressings of calcium nitrate[21] and urea,[23] however, showed that they were more dangerous than ammonium sulphate. If these forms of nitrogen are used in compound fertilizers, existing combine drills may not be satisfactory and safer methods of manuring may be required. New types of

coulter, which separate seed and fertilizer in the row, would lessen the incidence of "fertilizer scorch".

Combine drills are also used to sow grasses, peas and beans and clovers, but only superphosphate should be drilled with the seed, because other fertilizers may damage germination. A small drilled dose of superphosphate gave grass seeds a rapid start.[8] For peas and beans, broadcast dressings of PK granular fertilizers were of little value, and combine-drilling was often dangerous. Fertilizers placed 2 in. to the side of the seed and 3 in. below the soil surface were safe, however, and gave worthwhile gains in yields.[1,3,4,5,19] Conversion sets for sideband placement are now available for most makes of combine drill.[14]

Sideband Placement

Other crops grown in wide rows are generally sown with row-crop drills, which are not normally fitted with fertilizer hoppers. Broadcasting and sideband placement (2 in. to the side of the seed), both gave similar yields of sugar beet,[3,4] although early growth was much improved by placed fertilizers; contact placement was dangerous and decreased plant number and yields. However, sideband placement improved yields of brassicas (cabbage and kale) and many horticultural crops[7,9,19]; it also gave produce of more uniform quality which was ready to market sooner than when fertilizer was broadcast. Large benefits are unlikely, however, on old and heavily manured market-gardens. In general, crops with a short growing season or poorly developed root system (peas, onions, sweet corn) benefited from sideband placement, whereas crops with taproots and a long growing season (sugar beet and lucerne) did not.

Potatoes need liberal manuring for full yields and even with ploughed-down dressings of farmyard manure, heavy doses of fertilizers are still needed. Numerous experiments have shown that broadcast dressings are not efficient,[2,6,18,19] and that for potatoes planted in the furrows of ridged land, fertilizers should be broadcast before the ridges are split back to cover the seed tubers.[2] Broadcast fertilizers were only two-thirds as efficient as equivalent dressings placed to the side of the seed for potatoes planted by machines working from the flat.[6]

Many planters have fertilizer attachments, from which fertilizer flows into the planting shoes and, therefore, ultimately into contact with the seed. This method is as satisfactory as sideband placement, provided the seed tubers are planted in deep, moist seedbeds and rain follows planting, but it may check growth and diminish yield during dry springs or in rough seedbeds, or when compound fertilizers containing nitrogen as nitrate or urea are used. The weather cannot be predicted and farmers should therefore modify planters so that fertilizers can be drilled safely in one or two bands, each 3 in. to the side of the seed centre. Concentrated compound fertilizers simplify the mechanical problems involved, because less fertilizer is needed on the planter; the

lower delivery rates should also diminish the risk of blocked fertilizer coulters. Mid-season top dressings of nitrogen or potash were of less value to potatoes than equivalent seedbed dressings.[10, 13]

Summary

Broadcasting is adequate for grassland, but not for many other crops. Combine drills increase the yields of cereals because the fertilizer is used more efficiently; combine-drilled superphosphate improves the establishment of grass and clover seeds. Suitably modified combine drills may also be used with benefit to place fertilizers to the side of crops sown in wider rows. Potatoes need the rapid start given by placed fertilizers; contact placement is often dangerous however, but sideband placement is safe.

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An Advisory Project on Barley Manuring

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IMPROVED AGRICULTURAL KNOWLEDGE is often too slowly adopted on farms. Well-planned advisory projects, based upon local testing and demonstration designed for specific areas and conditions of management help to hasten the process. The project described in this article is not put forward as a thoroughly planned and executed example, but as a rough prototype which shows the possibilities of this type of planned advice in situations suitable for the group approach.

The area concerned in the project is the block of relatively uniform limestone soil extending to some 20,000 acres in north Kesteven. This land has almost all been farmed for many years on an arable rotation. Since sugar beet became popular, this rotation has commonly been of the following type: sugar beet, barley, barley, 1-year ley, potatoes, wheat, barley. The root crops are normally given liberal dressings of concentrated complete fertilizer, with farmyard manure sometimes being given for the potatoes and kainit for the sugar beet. Soil analysis almost invariably gives a pH of around 8 with phosphate and potash seldom seriously deficient. Combine drilling of fertilizer with the corn crops has been almost universal in recent years. The average annual rainfall for this area is about 24 in. and, on this free-draining land, farmers aim to drill the bulk of the barley crop by the end of March or early April.

Why was the Project Started?

In the years after the last war, farmers were expressing dissatisfaction with the yield of barley—the crop which occupied a larger acreage than any other. The estimated average yield for the area for 1949 was around 22 cwt per acre. Observers in this area a century before[1] had mentioned common yields of 24 cwt and the Danish national average in 1949 was 27·6 cwt per acre. Scandinavian varieties of barley were already being commonly grown in north Kesteven in 1949 and it was not surprising that local farmers were anxious to increase yields. At that time no survey of fertilizer practice had been carried out in this limestone region, and it is only possible to say that low-nitrogen compounds of the National No. 1 (7% N:7% P_2O_5:10½% K_2O) type were the general rule. It is worth noting that the number of sheep kept on these farms is nowadays very much less than 100 years ago, when half the total area was frequently under grazing leys and roots for folding.

* Now stationed in Shropshire.

Is this a Possible Answer?

Russell and Bishop[2] had shown in 1933 that 1½ cwt sulphate of ammonia was a satisfactory dressing of nitrogen for the varieties of barley grown at that time, both for quality and quantity. They showed that phosphate gave little return and suggested that residues from phosphate fertilizers given to previous crops in the rotation were likely to be sufficient for barley for two succeeding seasons. Of potash they said little but implied that it might be unimportant. In 1941 Crowther and Yates[3] summarized the experimental information on barley manuring since 1900. This showed that 1·2 cwt sulphate of ammonia gave an excellent response in yield, but that superphosphate and muriate of potash hardly paid for themselves, even though trial sites had often been chosen as likely to be deficient in these elements. A possible solution to the problem of low barley yields in north Kesteven appeared to be an increase in the nitrogenous dressing.

Trials to Test Various Fertilizer Dressings

It is not intended to describe in detail the series of trials which have been carried out by County N.A.A.S. staff in conjunction with the Regional specialists. The essential features are that they have all been in simple, replicated, randomized blocks and all operations have been carried out in conditions and under systems of management representative of the area—as described above. We began in 1950 by comparing 3 cwt of National No. 1, combine-drilled* with the same dressing plus additional straight nitrogen, phosphate or potash in the seedbed. In subsequent years various compounds and straight granular nitrogenous fertilizer were tested at various rates. In 1959 the trial crop was grown after barley, which was combine-drilled with Nitro-Chalk in 1958, after sugar beet in 1957. The main conclusion arising from all these trials has been that it paid to combine drill 60 lb granular nitrogen per acre under the chosen circumstances. The inclusion of phosphate and/or potash in a granular compound has never given an improvement in yield.

Germination has been noticeably checked by heavy fertilization with the seed, but this effect has never persisted until harvest. Ripening has not been retarded by straight nitrogenous manuring at 60 lb per acre. Under-sown leys are stunted by the heavier crops grown with high nitrogenous fertilizer, but observation in the following seasons has shown no noticeable effect on the yield of the ley.

A more difficult factor is the effect of manuring for high yield upon the quality of the barley as it is likely to be reflected in the price received. In the north Kesteven trial fields, barley was being grown either for feed or for seed, and malting quality was not attempted.

* The fertilizer in the box was weighed before and after drilling individual treatments to calculate accurately the actual rates of application which may differ slightly from those intended.

The proportion of the British barley crop now taken for malting for beer is, in fact, less than one-third, compared with two-thirds before the war.[4] Farmers growing the now popular variety "Proctor" often hope for a "malting" sample, but tend to think that so many factors outside their control affect the price which they ultimately receive, that they aim boldly for yield up to the limit of the standing ability of the crop.

A number of experiments since 1950 have supported the results obtained from the north Kesteven trials. At the Norfolk Agricultural Station between 1950 and 1953,[5] at High Mowthorpe Experimental Husbandry Farm between 1952 and 1954[6] and in a series of trials conducted by the County Farm Institute in Hertfordshire between 1953 and 1956,[7] nitrogen in the seedbed was shown to have an outstanding influence on yield. Recent Rothamsted work has also pointed to the superiority of combine-drilled compared with broadcast nitrogenous dressings, with the suggestion that $2\frac{1}{2}$ cwt sulphate of ammonia per acre may be the optimum for yield in some conditions. The responses to phosphate and potash are mentioned only in the Hertfordshire work where, over a range of soils, they were small.

Demonstration and Evaluation

The plots described in this article have all been on roadside sites, and, in recent years as we have gained confidence in the reliability of our results, they have been suitably signboarded and used as demonstrations. Results have been used in individual advisory work, in local corn market exhibits, in advisory publications and at farmers' meetings.

Local contact with the area in question gives the general impression that the rate of nitrogenous fertilizer used for barley has gone up considerably during these ten years and many farmers are now giving 40 lb or more per acre. Most of them have been applying this nitrogen in compounds with similar quantities of phosphates and potash. Nevertheless, several farmers have taken N.A.A.S. advice and used a fertilizer with a 15% N:5% P_2O_5:5% K_2O analysis of which approximately 100 tons were manufactured locally to our specification in 1957 and again in 1958. In 1959, farmers have drilled with straight granular nitrogen a total of more than 1,000 acres of spring corn, grown in rotation with roots. The high-nitrogen spring corn fertilizers now being manufactured by several firms are increasing in popularity. The average yields of barley have also increased by about 5 cwt per acre since 1949.

Higher Yields and Lower Production Costs

Valuable information is given by Messrs. Smith's Potato Estates which annually grow an average of some 500 acres of barley on Lincolnshire limestone soils. Careful records are maintained by this Estate and Mr. J. Ireson, the General Manager, has kindly allowed his figures to

be quoted. The average barley yield was 22·5 cwt in 1951, but rose steadily to 29·2 cwt in 1957. During this time the rate of nitrogen application per acre rose from 14 lb to 45 lb. In 1957 the higher rate of nitrogen was achieved mainly by applying more complete compound fertilizer, but in 1958 200 acres of barley were drilled with 3 cwt per acre of Nitro-Chalk and averaged 28 cwt per acre in that very unfavourable season. By altering their fertilizer dressings for barley in this way, largely on N.A.A.S. advice, Smith's Potato Estates have not only considerably increased their yields but have also progressively reduced the cost of barley production by about £2 per ton.

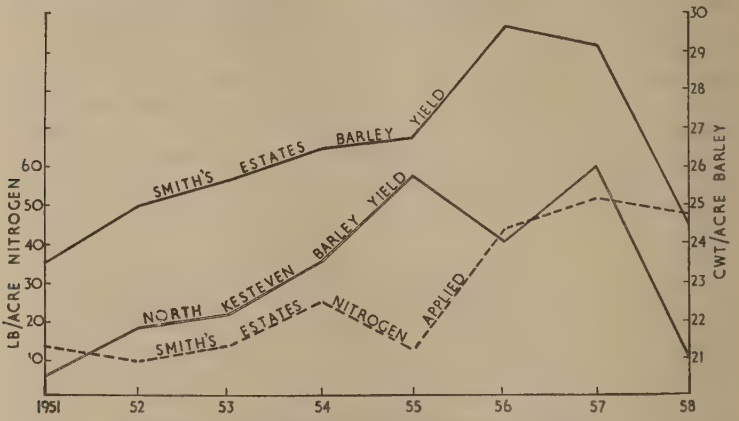

Fig. 1. Comparative Barley Yields, 1951–58.

In the evaluation of an advisory project it is seldom easy to isolate the effect of the project itself from other influences. Ideally, all these other influences are brought together within the project. In the present example it is not claimed that N.A.A.S. advice was the only, or even the most important source of influence upon local practice in barley manuring. In other parts of eastern England recent surveys have shown that there too, the rate of nitrogenous manuring for barley has risen; but the NPK ratio has remained around 1:1:1 in those areas where the "manuring of cereals seems to be virtually independent of previous cropping".[8] It would seem reasonable to claim that north Kesteven has made better-than-average progress in the economic manuring of barley as a result of N.A.A.S. advisory work.

Improving the Project

The work described here was not originally conceived as a project and has been carried out on a shoe-string as a small item in local N.A.A.S. work. It does, however, show the possibilities inherent in this approach to advisory work. North Kesteven barley yields have improved greatly

in ten years, but Danish yields have also increased and are still well ahead of ours. Moreover, the need for further decisive reductions in unit cost of production is continually re-emphasized in the Review white papers. The first step in an improved advisory project on barley manuring would be a more accurate survey of local rotations, fertilizer use and barley yields. A greater number of trial-demonstrations—say six at well-chosen points within an area of 20,000 acres—would spread the information quicker. The co-operation of fertilizer manufacturers and merchants could be enlisted. A more thorough exploitation of the demonstration results by all available advisory methods would lead to a quicker adoption of the recommended practice. In farming, as in all other businesses, success often depends upon the *speedy* adoption of improvements in technique. Advisory work succeeds when it helps to shorten this time-lag, always provided that it is based upon sound experimentation and trial.

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Blood Groups and Poultry Breeding

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THE INTEREST of blood groups lies in the fact that they represent a few accurately identifiable inherited characteristics of chickens which may be used as an aid to selection for improvement of valuable economic characteristics in "hybrid" production. This system of breeding involves the utilization of heterosis (loosely called hybrid vigour) in one form or another, for it has long been realized that this can give an extra boost in livability and egg production not attained by pure breeding alone. Until fairly recently the major sales in this country were of the first crosses of two good pure breeds, which were assumed, not always correctly, to be superior to either pure breed alone. The only selective improvement carried out was within each pure breed, and cross-bred performance data were not utilized in selection.

Hybrid Production

The other more modern methods of utilization of heterosis are basically three in number, and come under the general title of hybrid production. One is the method of crossing inbred lines, three or four at a time, which was originally applied to poultry by Henry B. Wallace of the Hy-Line company in Iowa; another of crossing strains within or between breeds, and the last the method of recurrent selection. These methods depend in principle on testing the performance of the crossed product bird rather than of the parental types, and then using this information to select the most suitable parents.

In the inbred-cross or strain-cross method, selection is between a number of inbred lines, or strains, those which nick best being selected, while in recurrent selection the selection is between different individuals, usually males, of a breed or strain. The males which nick best with another strain are mated to the sisters of other such selected males, and the strain can be improved in nickability with little or no inbreeding. Such recurrent selection may also be carried out reciprocally. The amount of testing necessary to produce a superior product by these methods, and to stay ahead of competitors, is enormous in amount and therefore costly. In the U.S.A. both the Hy-Line company and some of its competitors, such as DeKalb, were able to subsidize the costly development of hybrid chickens from the sales of the already successful hybrid maize. In this country only a very few firms of breeders were large enough to embark upon the development of hybrids. Blood grouping can offer very considerable short cuts in the development of superior hybrids, and thus save some of the money which must otherwise be spent on their development.

Antigens and Antibodies

The blood groups are determined by certain inherited characteristics of the red cells of the blood, called antigens. These are specific chemical structures on the cell surface, having two important properties. Firstly, if the red cells are injected into other chickens, their antigens stimulate the formation of specific antibodies in the blood serum. This response is part of the body's natural protective mechanism, although normally of course it is used as a protection against invading bacteria or viruses during an attack of disease. The antigens carried by the invading micro-organisms stimulate the production of specific antibodies, which then attack and destroy the micro-organisms concerned.

This leads us to the second property of red cell antigens, that they combine with their specific antibodies, the combination being followed by a clumping together (agglutination) of the red cells into masses large enough to be seen with the naked eye. In the body this is part of the destructive process, but we can make use of this effect to identify the blood groups. A suspension of red blood cells will be clumped when it is mixed in a test-tube with a specific antibody. This antibody is contained in the blood serum (the fluid left after removal of cells) obtained from a chicken which has received injections of the same or related blood cells. Research into the relationships of the antigens of the red cells of different individuals along these lines has shown that there are six separate series of antigens, known by the letters A, B, C, D, L, N. Each of these series possesses several alternatives, A_1, A_2, A_3, A_4, etc.

Further study of the inheritance of these characters shows that each antigen is determined by a single gene, that each series of antigens is determined by a different position on the chromosomes (a "locus"), and that the alternatives within each series are determined by the alternative genes ("multiple alleles") possible at a single such position or "locus". Thus the red cells of every chicken have either one or two of the alternative antigens of all six series present on their surface.

Blood Group Constitutions

The permutations possible from several alternatives in six series are very numerous, and it can be said that no two chickens will be exactly alike in their antigenic formula unless they are highly inbred. This enormous variation in the blood group constitutions of individuals can cause tremendous difficulties in sorting out the separate antigens concerned. Two individuals randomly chosen from a non-inbred strain might have the following blood group constitutions:

I	A6A8	B2B4	C5C7	D2D3	L1L2	N1N1
II	A5A7	B1B4	C4C6	D3D4	L1L1	N1N2

Injection of red blood cells from bird I to bird II would be likely to produce a mixture of antibodies which would agglutinate red blood cells carrying any of the following seven antigens:

A6A8 B2 C5C7 D2 L2

The reciprocal injection would probably produce antibodies reacting with any of the following seven antigens:

A5A7 B1 C4C6 D4 N2

The basic rule in antibody production is that an animal cannot produce antibodies against any injected antigens which it already possesses itself. The above two antibody-mixtures could hardly serve as specific diagnostic sera, and to make the task of identification and sorting out easier, it is almost essential to use highly inbred lines. Inbreeding tends to increase the purity or homozygosity of genes, and in highly inbred lines such as those bred at Reaseheath it is sometimes possible to find families such as this:

SIRE	×	DAM
A2A2		A2A2
B3B4		B3B4
C4C4		C4C4
D6D6		D6D6
L1L1		L1L1
N2N2		N2N2

giving
PROGENY

B3B3 or B3B4 or B4B4
(All alike at A, C, D, L, N)

This family appears to be pure for A, C, D, L, N, but impure for B. If red blood cells were injected from the sire into the dam, or vice versa, no antibodies would result, since these birds are alike in all antigens. But if the sire's blood cells (B3B4) were injected into the first type of offspring shown (i.e., B3B3), pure antibody for B4 would result. Similarly, cells of type B3B4 injected into B4B4 progeny would produce pure antibody for B3. Blood is drawn from the recipient of such injections, the serum is separated from the cells, and then used to distinguish B4 cells from B3 cells or vice versa, in an agglutination test. This may be carried out in small tubes, or on perspex "influenza" plates—as used in virus research.

Connection between Blood Groups and Performance

The first hint that these inherited blood antigens were connected with livability and production was inferred from the finding independently by the writer at Reaseheath and by Americans at Texas State College that the antigen genes did not become pure or homozygous with close inbreeding as they should according to theory, and as probably most other genes did. The obvious explanation of this would be that individual birds impure or heterozygous for these genes had an advantage over the pure homozygotes in survival value—fertility, hatchability, egg production, livability. For so long as heterozygotes were preferred in each generation of inbreeding, it would be impossible for the genes to become pure. Evidence for this was forthcoming from further study at Reaseheath and at Texas. Antigen heterozygotes were

superior to homozygotes in sire fertility, dam egg production and size of family hatched and reared, and in progeny survival up to six months of age. These results were of immediate interest to theoretical geneticists, as answering some vital questions about the theory of inbreeding. No sensible commercial breeder would want to utilize these findings, since inbred lines as such are not profitable. But *once* the principle was established that there was a connection of some sort between blood groups and performance in inbred lines, it was thought worthwhile to see if similar correlations might apply in a commercial chicken produced by crosses of such lines. In this case the advantage of heterozygotes over homozygotes was not of direct interest. Instead, the question would arise whether different heterozygous combinations might be associated with different performance levels in cross-bred birds which would all be heterozygous.

Hy-Line in America were the pioneers in this field. Perhaps because they possessed many inbred lines which they used to make their famous four-way cross, they were more alive than most breeders to the potential usefulness of the findings with blood groups in inbred lines. They have very kindly allowed the writer to quote some of their results. Firstly, they confirmed on a larger scale the University findings within inbred lines, but using the B locus alone, since the work at Texas had concentrated on this. They then progressed to the investigation of the correlation of the B blood groups with production, in crosses to make hybrids. The commercial hybrid was a four-way cross of inbred lines, symbolized as $(W \times X) \times (Y \times Z)$. The method used was to find which blood antigens of each line in turn combined best with the other lines to give the best final cross. An example of the sort of experiment made is as follows: Line W, being considerably inbred, had only two B antigens, B1 and B2. Inbred males of this line were sorted into the three possible types B1B1, B1B2, B2B2, and each of these groups of males was used to sire three-way cross progeny on dams of the cross $Y \times Z$. The pullets sired by B2B2 males were superior to those sired by B1B1 males in egg production and livability, while those sired by B1B2 were intermediate. This result indicates that birds carrying antigenic combinations containing B2 + any antigen contributed by YZ were superior to those containing B1 + any from YZ.

On the basis of these results, line W was selected so as to be pure for B2, when used to make crosses on YZ. Similarly, crosses of blood-typed males of line X on YZ showed B4 to be preferred to B3, in the combinations produced in the progeny. Finally, comparisons of single-cross males from WX were made for combinability with YZ. Four years of comparison of two commercial hybrids made in the same way, but differing only in one B antigen, showed that the preferred antigen gave superior livability and egg production in almost every case, with better profitability. It is very important to note that these results were specific, applying only to this particular cross. Thus in the above work, B4 from line X gave superior combinability with the females of type YZ. But

in other experiments, Hy-Line showed that if the males of type WX were used on an entirely different female single-cross (say P × Q), then B3 had superior combinability. Thus, we cannot conclude that B4 is a preferred blood type in all circumstances, but merely that it is superior in the specific cross with female of type YZ.

This is one limitation to the usefulness of blood grouping applied to conventional pure breeding, for in non-inbred populations there will be a wide range of possible B blood group types, and it appears that superior performance and livability will perhaps be associated with only a few of the very many possible B combinations.

Further Advances using Blood Groups

It is only when the breeder has already found a high degree of nicking between certain lines or strains that he can perhaps make *further* advances using blood groups. A second trouble is the difficulty of identifying blood groups already referred to. Unless the purity of the nicking strain has been considerably increased by inbreeding it is going to be extremely difficult technically to identify all the antigens present. This difficulty might be less where a breeder has practised recurrent selection. For if two strains have been crossed together for some years, and selected on the basis of crossed-progeny performance, we might hope that the frequency of the preferred combinations of the blood groups in the progeny would be increased, which would obviously imply that each strain would have acquired a higher frequency of the blood group contributing to such combinations. This would have the effect of partially purifying each parent strain for blood groups, thus perhaps making identification easier.

Although the Hy-Line results with the B locus alone have been striking, and have already yielded them considerable commercial benefits in marketing a superior hybrid, it should be realized that only the surface of this subject has been scratched. The writer's work at Cambridge with the Reaseheath inbred lines showed that the L locus was more powerful than B in its heterotic effects, while others were also involved. If these other loci prove to be as effective in inbred-crossing, or in recurrent selection, as the B locus did in the Hy-Line work, we may expect a valuable future for the application of blood group research in the development of superior commercial hybrids.

Farm Management Group Meetings in Cornwall

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THE TYPE OF ADVICE given by the Agricultural Advisory Officer has changed markedly during recent years. This has been due, primarily, to the need for planning economic production, instead of the war-time and early post-war needs of maximum production, irrespective of costs. The change of emphasis has entailed the application of economic principles to almost every major piece of advice given to a farmer, but the N.A.A.S. have accepted this challenge, for today farm management advice occupies a prominent place in our work.

It is by no means easy to introduce farmers to the new conception of applying business principles to farming methods and as so much personal information has to pass between farmer and adviser, it is little wonder that many farmers are shy of these new techniques. Success largely depends on obtaining the interest of the farmers themselves in the subject and their confidence in the ability of the adviser.

Local Conditions Demand Variety of Approach

Various methods have been tried over the country to further the application of farm management principles to the planning of farm production. The approach discussed in this article has been used in Cornwall over the past few years, but obviously there can be no perfect blueprint applicable to all conditions. A previous article on this subject in the *N.A.A.S. Quarterly Review* reports on a method used in Lincolnshire,[1] and an article by the writer in *The Agricultural Review*, describes a method applied to efficient large-scale farming conditions in Hampshire.[2]

The problems in Cornwall are completely different. The county contains some 6,500 holdings of less than 20 acres, together with a further 5,500 family farms between 20 and 100 acres. With so many small farmers tied to their holdings seven days a week, few have the time or inclination to attend farm walks and meetings, nor do many of them appreciate the need to keep good records. What would be the best method of interesting these small men in farm management? Could we get them to come to meetings, and what sort of meeting would be the most effective?

To see the problem in perspective it has to be remembered that the need for economic advice is greater and more urgent in the grassland areas, whereas in the areas devoted to arable farming, falls in farm incomes can often be overcome by increasing cereal yields. In the west, the problem is even more complicated, because it is often necessary to intensify farm systems and re-deploy existing capital resources.

Another problem we faced was the possibility that if the farming

community quickly accepted these fundamentals, we might very easily stimulate a greater demand than we could adequately manage. So we decided that the method of publicity must to some extent be self-satisfying. We must teach farmers to apply the principles of farm planning to their simpler problems, seeking N.A.A.S. help only when they were in real difficulties.

Choosing Acceptable Surroundings and Company

After much thought and discussion, we came to the conclusion that small groups meeting in the evenings for a somewhat "social" occasion would be most likely to succeed. After a hard day's work, comfortable and warm conditions would be necessary, preferably in familiar surroundings. In the winter of 1954–55, seven farmers in the Helston district were approached to act as hosts in their farmhouse kitchens, to small groups of farmers. These men readily agreed and their wives volunteered to provide refreshment for the guests. Careful selection of those invited was necessary, to ensure both that they would benefit from the subject to be discussed, and were all acceptable to one another and to their host.

The next, and probably more difficult problem, was to decide the best way to "put across" the story of farm management and what it could achieve for the individual farmer. For these seven meetings a story was prepared on lantern slides, setting out the physical and economic data of a typical west Cornwall "Dairy and Pigs" farm. The farm was an actual one; performance was measured by using the average figures from Bristol University's Farm Management Survey as comparisons.

The meetings were kept informal with a break for refreshments and discussion. From 12–30 guests were invited to the Farmhouse meeting, depending upon the size of the room available at the host's farm. Finally, some of the farmers from the seven preliminary meetings who were keenly interested met for a second run-through and discussion of the farm story.

Success Encourages Extension of Technique

The results of these first series of meetings were very promising. Practically all the farmers invited turned up to the meetings; those who did not had a reasonable excuse for not doing so. As a result of our experience, it was decided to extend the idea to the whole county in the 1955–56 winter. Some districts preferred to meet in hotels, whilst others used farmer hosts in farmhouses. Further sets of slides were prepared for real farms typical of north Cornwall and mid-Cornwall, the former "livestock rearing" and the latter "mixed farming with some dairying". The performance of farms was again compared with the Bristol University Farm Management Survey. About 30 groups met and discussed one of these three typical farms during 1955–56. In the Helston district, fresh farmhouses were used to put over the west Cornwall farm

story. During the summer of 1955 a farm walk was held on a particular farm, to which the previous year's farmhouse groups were invited. During the winter months these groups met and discussed the results being obtained on this particular farm. Unfortunately, only limited financial data could be made public, but the expanding policy and good management points were brought out and fully discussed.

Evaluation leads to Simpler Presentation

After the year's work it was quite obvious that our idea of informal farmhouse meetings was successful, but some re-thinking was necessary to find a way of presenting farm management facts and figures in a more palatable form. It was generally agreed that the original three typical farm stories were too ambitious for the type of audience with which we had to deal. Further work ought to deal with simpler management checks, for we must not go too fast in our efforts to stimulate farmers to think in terms of economics in their farm planning. So during 1956–57 we dealt with feeding of dairy cows and partial budgeting. Feeding costs are the most important factor on the small dairy farm. If we could show how important feed costs were in dairying and how essential feed records were, we might persuade farmers to look critically at their own feeding, and real progress would have been made.

In the dairying areas feed costs were the subject of the meetings, together with the partial budgeting of the effects of adding cows to an existing herd, even when all the food was bought. Some long and heated discussions occurred at these meetings. In the stock rearing and mixed farming areas, partial budgets dealing with the substitution of beef for dairy together with the different methods of beef production and store rearing were discussed, for at that time beef was a subject uppermost in many farmers' minds. The details of the budgets have been published elsewhere.[3]

Visual Aids promote Understanding of Economic Problems

Discussions and farmer participation were everywhere better than in the previous year. We found that farmers had no difficulty in understanding partial budgeting and would argue with ease about the costs and output figures used. An interesting visual aid was developed, using a slide projector in conjunction with a flannelgraph.

A white flannel was pinned to a blackboard as a flannelgraph; it was also used as a screen for projecting the coloured slides. When the slide holder was empty, the projector light served to illuminate the flannelgraph on which the partial budget was put up step by step. Discussion followed each budget used. Originally the budgets were prepared on cardboard which was backed with sandpaper, but later in the year "Vybak" sheeting and "Zell-Em" plastic lettering was successfully substituted, sandpaper backing the "Vybak" as with the cardboard. Being more rigid than the cardboard, the "Vybak" was easier to transport and

use. In small rooms a 250-watt projector proved adequate, but in some large kitchens a higher-powered machine was necessary to obtain a good screening of a colour transparency.

Getting Farmers to Discuss Farm Management

So far the N.A.A.S. had been doing most of the talking. Meetings with partial budgeting had shown that farmers would readily take part, once they had grasped the principles involved. Therefore in 1957–58, it was decided to evolve subject matter in which the farmers themselves could take a more active part. This proposal meant taking a wider view of farm management than merely applying economic principles.

Models were made of a set of farm buildings on a 60-acre farm. These buildings would need considerable modification to meet the "farm plan" prepared by the N.A.A.S. This problem formed the basis of the Farmhouse meetings in the Truro district. The plan for the farm was given to the group, which then split into smaller groups to discuss what should be done to the buildings. A fixed amount of capital was allocated for the work. The proposals of the sub-groups were then discussed; finally, a "stock" solution arrived at in co-operation with the A.L.S. was demonstrated, using models to show the changes proposed.

For the north of the county, sheep were still an important part of the farming system, as well as promising to give a better financial return than beef. Moreover, many farmers were worried about the amount of milk being produced at that time. Partial budgets were prepared substituting sheep both for various methods of beef production and for dairy. These budgets have previously been written up and published in *Agriculture*.[4]

In other districts the teaching of principles continued; St. Columb worked on the comparison of the cost of home-produced feeds with purchased feed costs. Liskeard and St. Germans districts used a success story, where a farmer who had received N.A.A.S. farm management advice had trebled the net farm income in four years.

Larger Meetings now become Necessary

During this year there had been a limited demand for farm management advice from individual farmers, but we were not satisfied that the bulk of farmers had been initiated into what facilities and help the N.A.A.S. could offer. However, there was a growing demand for more and more farmers to be invited to one of the meetings. Such a demand had to be met, but the size of most kitchens prevented any large increase in numbers catered for, except by multiplying the number of meetings held. It was felt that present commitments were already as large as the staff could adequately manage.

To meet this need, during the 1958–59 season, three larger open invitation meetings were held in hotels in the Helston district, where,

as the pioneer district, meetings had been held in a number of farmhouses for three years previously. For these, the main financial results, profits, output, and major costs, for eleven farms in the district were analysed and compared. There were three groups according to size, and the good and bad points of management for each case were discussed. The attendances were good (60–100 at each) so the "11 farms" story was extended for use over the whole county. There were eleven meetings in all, and one special one for bank managers at their request. No audience was less than 30 and most were in the 60–100 range. Details of presentation and some of the economic data of the farms used have been published elsewhere.[5]

Build up the Story Step by Step

For presenting the data involved, small sections of "Vybak" plastic sheeting were used on which the profits, output and major costs were set out in plastic letters and figures. These were slid into a board similar to hymn boards used in churches. This method enabled the story of eleven farms to be built up step by step, without presenting a mass of figures to an audience all at once.

In the Penzance district, a further four meetings were held on similar lines, using the same method of presentation, but with the results of only six small farms of 23–32 acres in size. In neither case did we find that the farmers had any difficulty in following us. In fact, the arguments they brought up proved conclusively that they were following the story. There is no doubt that six farm financial results is better than eleven for this purpose, provided there are sufficient differences to make a good discussion. Other meetings in 1958–59 made use of models of farm buildings and layout problems and work routines in feeding pigs.

What of the Future?

Requests from individual farmers for management advice on the whole farm system have increased this year quite considerably. More and more farmers too, are discussing economics in the problems they bring to District Advisory Officers.

With the advent of the Small Farmer Scheme, District Advisory Officers are meeting and making plans with farmers with whom they have had little previous contact. If the principles behind the Small Farmer Scheme are to be fully realized, farm management advice will need to be given and taken by these farmers. We are hoping in due course to be able to get financial results from some of the best schemes, for presentation to groups of small farmers. These will, of necessity, include farm walks to show the technical progress achieved as well as the economic. Such work will be breaking into new ground, but we must try to interest our existing groups by presenting up-to-date economic problems which are topical due to the changing pattern of farming. We too, must be flexible and ready to vary our ideas and methods to meet changing circumstances.

Finally, it is emphasized that these ideas are the result of team work, by both past and present members of Cornwall N.A.A.S. staff. Although the writer is recording the details, many others have contributed to the development work and planning. We are also greatly indebted to the Farm Management Liaison Officers of Bristol II Province (Department of Economics) for their help and guidance in much of the early work.

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Chemical Weed Control and Grassland

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THE USE OF CHEMICALS for weed control has grown rapidly since 1945. Although their development on grassland has been less spectacular than on cereals, evidence has accumulated of their value in the establishment, maintenance, and renovation of pasture.

Chemicals which have been used successfully for control of broad-leaved weeds in grassland are MCPA, 2,4-D, MCPB, 2,4-DB and dinoseb. Dalapon and amino triazole have been studied for the control of grass weeds.

Broad-leaved Weeds

The effect of the weedkiller on the legume component of the sward is of primary importance, especially in young pastures, where clover damage is likely to have a long-lasting detrimental effect. For effective weed control 1–2 lb per acre* of MCPA or 2,4-D is required. The results of Holly in 1953,[3] showed appreciable reduction in growth of S.100 white clover following treatment with $\frac{1}{4}$ lb per acre of MCPA or 2,4-D at the 1st and 3rd trifoliate leaf stage. Holly also showed that 2,4-D was less toxic than MCPA to white clover, the converse being true for red clover, with an increase in resistance of both species with increasing age.

* All doses quoted refer to acid equivalent.

The β-oxidation system, which converts the inactive phenoxy-butyric herbicides into their active acetic homologues, was found to be present in many weeds, but poorly developed in red and white clovers. This discovery re-opened interest in the spraying of undersown cereals and establishing leys. MCPB and 2,4-DB are far less toxic to seedling red and white clover than MCPA and 2,4-D; Carpenter and Wilson, 1956,[3] placed the MCPB/MCPA toxicity ratio in the order of 8–10:1 for seedling white clover and 3–5:1 for seedling red clover. The same authors reported that differences in initial clover check resulting from MCPA and MCPB treatments frequently persisted for two seasons.

Edmond, 1957,[4] has shown reduced yields in white clover when MCPB is applied only to the soil as against applications confined to the foliage. Carpenter and Soundy, 1954,[3] showed that the reduction in cover leaf density of Kentish white clover was less under moderate than under slight weed infestation. This may have been so because under slight weed infestation more MCPB falls on the soil and is converted by soil micro-organisms into the acetic homologue which is subsequently taken up through the root.

In directly established pastures, herbicides reduce weed competition before the traditional method of annual weed control by early grazing and mowing can be carried out. Procumbent weeds such as chickweed and knotgrass, which are not easily controlled by grazing and mowing, are also resistant to MCPB and 2,4-DB. These weeds are controlled by dinoseb—the application of which is governed by the Agriculture (Poisonous Substances) Act, 1952—and can be applied to white clover at the 1–2 trifoliate leaf stage.

On established clover Elliot, 1956,[3] found significant reductions in ten out of thirteen trials in which MCPA or 2,4-D was applied at 2 lb per acre. In no instance did 2 lb per acre of MCPB or 2,4-DB result in significant reductions. Initial clover reduction has not always proved so serious in permanent pasture. Norman, 1954,[3] found an increase in clover content twelve months after spraying with 2 lb per acre 2,4-D amine, resulting from control of broad-leaved weeds. Willis,[10] working on buttercup control with MCPA, found less damage to white clover from a May spraying than from March or April applications, but Elliot[5] reported less damage from early applications. Willis also showed that there was more damage where the original clover content was low.

Weed Control and Grassland Productivity

Considerable knowledge has accumulated on the response of grassland weeds to the various herbicides, and this is condensed in Tables III and IV of the Weed Control Handbook.[1] The effect of weed control on grassland productivity has received less attention. Halliday and Templeman[8] found a significant increase of useful grasses and legumes in established leys and permanent grass treated with MCPA, as a result of

reduced weed competition. These results were confirmed by Jeater, 1958,[3] and Baker and Evans, 1958.[3] Total yield of herbage, however, was not increased by spraying alone. The last results also showed an increase in useful grasses and clovers in the year of treatment amounting to 180 lb dry matter per acre, following spraying with 1½ lb per acre MCPA. Nitro-Chalk at 6 cwt per acre produced an increase of 900 lb, and MCPA plus Nitro-Chalk produced an increase of 1,880 lb. Apparently the grasses were better able to utilize applied nitrogen without competition from weeds.

Halliday and Templeman assessed the yield of useful herbage from a hay cut and recorded a significant reduction in clover content after treatment with 2 lb per acre of MCPA. The management given by Jeater consisted of four silage cuts in succession over a period of two years; clover was eliminated from all plots by the second year, including those sprayed with MCPB and 2,4-DB. Baker and Evans imposed a lenient grazing management. They reported that the clover content, after an initial reduction following spraying, varied between 7 and 10 per cent both on the sprayed and unsprayed plots three months after spraying. These results clearly show that management following spraying is as important as choice of chemical if clover content is to be maintained in a sward. This is important since the range of weeds controlled by MCPB and 2,4-DB is not as large as that controlled by their acetic homologues.

Grass Weeds

Davies, 1953,[3] states "Almost 75 per cent of the permanent grassland of this country is dominated by weed grasses, in particular bent and fog. These must be regarded as serious pasture weeds of lowland Britain." The development of dalapon (2,2 dichloropropionic acid), a very effective grass-killer, has encouraged much research into the study of selective grass control and of herbicidal treatment in preparation for oversowing.

Reports on the toxicity of dalapon to different grass species are variable. Fryer and Chancellor,1958,[3] found timothy resistant to over 19 lb per acre, cocksfoot and meadow fescue resistant up to doses of 11 lb.; ryegrass was, however, killed by all doses over 1 lb. No difference between varieties was apparent. In other experiments, the same authors found ryegrass to be markedly resistant in a well-grazed acid upland pasture. Thompson, 1958,[4] working in New Zealand on a mixed sward reported that cocksfoot was less tolerant to 5 lb of dalapon than ryegrass. Recent work by Thompson, 1959,[4] suggests that the susceptibility of grasses to dalapon is dependent on the amount of leaf present at spraying. Similar variations in results apply to susceptibility of weed grasses. Much more research under carefully controlled conditions is necessary before recommendations can be made for the selective control of weed grasses in pasture.

Sward Destruction prior to Oversowing

There is still a large acreage of unproductive permanent pasture, much of which is on land that is too wet, steep, or shallow to plough. Investigations have been carried out with chemicals to give partial or complete destruction of such swards as a pre-treatment for oversowing, and to reduce the cultivations necessary for reseeding. Since a control of grass and broad-leaved species is required, mixtures of chemicals have been used. Mixtures of dalapon plus 2,4-D or dalapon plus amino triazole have given encouraging results.

Experiments at The Grassland Research Institute[2] showed a ryegrass content of 37 per cent one year after sowing, following suppression of the original sward by 3 lb per acre of dalapon plus 1 lb per acre of 2,4-D. This compared favourably with a 24 per cent content of unsown ryegrass attained after six years of manuring and controlled sheep grazing on the same field. Gardner[7] obtained ryegrass contents of 20–40 per cent one year after oversowing *Nardus*, *Molinia*, and *Agrostis*/fescue pastures that had first been treated with dalapon at rates up to 10 lb per acre. Elliot, 1958,[3] reported successful establishment of timothy/meadow fescue leys on flood meadows previously dominated by red fescue or tussock grass; the dalapon treatment was followed by pitchpoling or rotary cultivation. New Zealand workers have also reported success in many trials.

Some of the limitations of the technique were described by Ormrod, 1958,[3] following a series of experiments on difficult land. Heavy rain soon after spraying reduced the efficiency of the chemicals. 2,4-D did not always give adequate control of broad-leaved weeds which spread rapidly in the absence of grass competition. The presence of a thick acid mat seriously interfered with any attempts at seedbed preparation. Gardner[7] reported failure where moss was abundant in the original herbage and no cultivations were carried out. Persistence of the chemical in the soil can seriously affect establishment if sowing is carried out too soon after spraying. Persistency of dalapon is proportional to the rate of chemical applied but is prolonged in dry or cold weather.[9] Normally grass and clover seeds can be sown one month after spraying at rates up to 10 lb per acre. The technique must still be considered to be in the experimental stage.

In conclusion, it can be said that chemicals can eradicate many persistent weeds from pastures more quickly than is possible by cultural methods and without resorting to ploughing. But chemical treatment must only be regarded as an additional tool to good grassland management, for it will only prove profitable where the underlying causes of weed invasion are recognized and rectified.

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The Economic Importance of Virus Diseases of Fruit Trees in England

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IF AN ATTEMPT were made to cover the whole field of fruit tree virus diseases, this account would resemble an auctioneer's catalogue! It is therefore restricted mainly to the virus diseases that seem important in English fruit orchards (excluding cider and perry), either because they severely affect the trees or because of their prevalence.

It cannot be stressed too often that a disease may have slight effects on individual plants and yet be of considerable economic importance because of its prevalence in the crop. Virus diseases of this type are common in fruit trees because they have been perpetuated by vegetative propagation of rootstocks or scions, whereas viruses producing conspicuous symptoms must rely on vectors other than man for their survival.

Viruses that are latent or cause only inconspicuous symptoms may also have, or once have had, other means of perpetuation, but many now seem to depend on the vegetative propagation of their hosts. It is for this reason that efforts have been directed in many countries to the supply of virus-tested material for propagators and to certification schemes to maintain health standards in the nursery.

Few attempts have been made to estimate the losses caused by virus

diseases of tree crops. The little information that is available relates to severe diseases that virtually stop the cropping of infected trees or render the fruit unsaleable. Such diseases as swollen shoot of cacao, cherry Pfeffinger disease in Switzerland, little cherry in the Kootenay district of British Columbia, plum pox in Yugoslavia, peach mosaic, peach yellows and phony peach in the U.S.A. are obviously of great economic importance, and a minimum estimate of the losses can be calculated from a count of the infected trees. We have two diseases of this sort in England—both in cherry—but they have become epidemic only in certain areas, and undoubtedly greater losses are caused by viruses that reduce crop without obviously damaging the trees. Field experiments are being conducted at East Malling to measure the effect of so-called mild viruses on the growth and yield of fruit trees, but only the cherry trials are old enough to have produced crops that can be analysed statistically.

Cherry

Two virus diseases of cherry in England either rapidly kill or soon stop the fruiting of mature trees. European rasp leaf is now known to be a complex disease in the sense that a number of different, probably unrelated, viruses produce similar effects and may not be distinguished from each other by the symptoms they produce on cherry.

At least two of these viruses are soil-borne (one is nematode-transmitted) and were previously known to infect raspberry and strawberry.[2,3,4] It follows that cherries should not be planted on sites where soil-borne diseases of soft fruit have occurred, and also that strawberries and raspberries should not follow cherry trees which have succumbed to rasp leaf disease. Leaf roll is also a complex disease and may be caused by one or other of at least two viruses; one of these has properties suggesting that it is soil-borne, while the other may be transmitted by insects.

Rasp leaf and leaf roll diseases are widely distributed in southern England and have caused severe damage in certain orchards. No detailed survey has yet been made, but so far as is known these diseases are not prevalent, and their importance lies in their potential threat to cherry production if they were allowed to spread. This is true also of little cherry disease. The one confirmed outbreak in the West Midlands has been eradicated, but several suspected cases are being investigated. Little cherry disease may not prove to be as disastrous in our varieties as it was in 'Lambert' in British Columbia, but even a moderate reduction in fruit size would result in considerable financial loss if the disease became widespread; a potentially dangerous situation exists with the virus probably widely dispersed in Japanese flowering cherries.[15]

The virus canker of 'Frogmore' cherry produces a severe disease in this variety, to which so far it seems to be restricted. Yield is considerably reduced by the death of the fruiting spurs and the disease could be mistaken for bacterial canker.[8]

The chief factor restricting the production of cherry fruit (on varieties and in orchards where bacterial canker is not limiting the growth of the trees) is infection with latent viruses. These have insidious effects, their hosts seeming in good health and yet producing poor yields. Some latent viruses have halved the yield of sweet cherries, while others reduced the crop by a quarter. Several viruses of this type are extremely widespread in English orchards (to the extent of over 90 per cent of the trees that have been tested). This is not surprising in view of their prevalence in nursery trees. As the latter are usually grown from scions collected from orchard trees the situation is self-perpetuating, unless the propagator is supplied with virus-tested scion wood.

Experiments at East Malling have now proved what has long been suspected—that latent viruses prolong the establishment period of young cherry trees and reduce the crop of mature trees. Thus at 6 years old, virus-free 'Early Rivers' trees produced 23 lb fruit per tree compared with 7 lb from symptomless trees infected with necrotic ring spot and sour cherry yellows viruses. The same latent viruses inoculated into 28-year-old 'Early Rivers' reduced the crop to 83 lb per tree compared with 195 lb from healthy trees. European rusty mottle and rugose mosaic viruses had less effect than sour cherry yellows on growth and cropping of 'Early Rivers', 'Napoleon' and 'Merton Bigarreau' trees.[12]

Plum

Latent viruses are as prevalent in plum trees as in cherry, but less is known of their effect. Some viruses which produce no apparent symptoms in most varieties have a severe effect on others, and this is exemplified by two viruses prevalent in English orchards. The prune dwarf virus causes sterility and severely stunts some prune varieties, but has little effect on most varieties of plum. Similarly, the bark split virus[14] cripples some gage varieties but has *apparently* no effect on plum varieties such as 'Marjorie's Seedling' and 'Monarch'. Whether the word "apparently" can be omitted, or whether an effect will become evident later, as in our cherry trials, we shall know in a few years time.

One of the most common diseases, plum line pattern, is caused by the apple mosaic virus.[13] The symptoms are rather less conspicuous on most varieties of plum than on apple, but if the two hosts react in a comparable manner the yield of infected plum trees may, none the less, be well below that of healthy trees. In New Zealand line pattern is reported to halve the yield of Japanese plums.

Plum pox, or a similar disease, occurs only rarely in English orchards, but because it renders fruit unsaleable it is potentially dangerous.

Apple

Apple mosaic was one of the first fruit trees viruses to have its effect on yield accurately assessed.[7,10] A field trial showed that the variety of apple had a greater influence on the result than the strain of virus used. Thus a mild strain, almost symptomless in 'Cox's Orange Pippin', reduced the yield of this variety by 30 per cent—almost as much as a severe strain that caused defoliation; yet neither virus strain produced a significant reduction in the cropping of 'Newton Wonder'.

This striking difference in varietal response is repeated with other viruses infecting apple. Rubbery wood virus induces rubberiness on only a few varieties, such as 'Lord Lambourne', 'Golden Delicious', 'Sunset' and 'James Grieve', and even some of these are affected only by certain strains of the virus. Star crack virus produces symptoms on the fruit of several varieties, yet causes die-back and cankers only on 'Cox's Orange Pippin', as far as we know at present.[11] Chat fruit disease is recognized only on 'Lord Lambourne'.[5]

In addition to these virus diseases causing recognizable symptoms on commercial varieties of apple, we know that certain prevalent viruses can be detected only on specially selected indicator varieties such as *Malus platycarpa*.[6] These latent viruses may be important in rootstock selection; at least one stock, 'Virginia Crab', is damaged by the stem pitting virus carried without symptoms in some of our scion and clonal rootstock varieties. But it is true to say that latent infection is so prevalent in our scion varieties at present that we have no way of estimating even approximately the effect on growth and yield.

Pear

The virus diseases of pear are closely analogous to those of apple, stony pit taking the place of star crack, pear mosaic that of apple mosaic, the recently described pear bark blister[1] that of rubbery wood, and the latent viruses, quince stunt, sooty ring spot and bark necrosis[9] in lieu of the apple latent viruses. One disease of pears, vein yellows, which has no counterpart in apples, is however very prevalent indeed. It has a considerable effect on the growth of some varieties, particularly on young trees. The effect of pear viruses seems to have been reduced by the unconscious selection of tolerant varieties of both quince rootstocks and dessert pear scions, although this may not be so in perry pears.

At present there are no data from field trials to support the writer's impression that virus diseases are no less important in pears than in cherries, although their effects are more obvious in the latter.

Conclusions

Whilst we cannot, for want of data, at present place virus diseases of fruit trees in order of their economic importance, we can attempt to group them into four categories:

(A) those which are of local importance and which would cause severe losses if they became prevalent;

(B) those of importance because they probably reduce yield by 20 per cent or more and are already prevalent in orchards;

(C) those of importance only in a limited range of varieties;

(D) those which now seem unimportant on the present range of commercial varieties in Britain.

	A	B	C	D
Apple	Star crack	Mosaic	Chat fruit Rubbery wood	Stem pitting and other latents
Pear	Bark blister Stony pit	Vein yellows	Mosaic Red mottle	Quince stunt and other latents
Cherry	Rasp leaf Leaf roll Little cherry Virus canker	Necrotic ring spot Sour cherry yellows	Rugose mosaic Rusty mottle	Ring mottle
Plum	Pox	Stunt Prune dwarf	Line pattern Bark split Leaf roll	Green mottle and other latents

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Formulae for Average Sunshine Values

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AVERAGE SUNSHINE for the year, and for the four seasons can be found to a high degree of accuracy from formulae which depend on the distance from the nearest coast, the distance from the south coast and the height above sea level for any place in England and Wales.

A close examination of Fig. 1, showing the average means of daily duration of bright sunshine for the year as a whole brings forth some interesting points which could be summarized as follows:

Firstly, as might be expected, the areas with highest averages lie along the south coast.

Secondly, as is not realized quite so often, places further north have almost as high an average as the favoured south coast areas, if (and only if) they lie near the coast, especially the east coast.

The areas with the lowest averages are those furthest inland and at the greatest height above mean sea level.

Space here does not permit showing similar maps for individual months, but those given in a publication such as *Climatological Atlas of the British Isles*, issued by the Meteorological Office, exhibit the same characteristics.

This regularity of distribution suggests that it should be possible to work out empirical equations from which sunshine averages could be calculated using as variables:

(*a*) The distance from the nearest coast in tens of miles (CN)
(*b*) The distance from the south coast in tens of miles (CS)
(*c*) The height above sea level in hundreds of feet (H)

Such equations have recently been determined by the agricultural branch of the Meteorological Office and the average annual sunshine in hours per day is given for any place in England and Wales to a fair degree of accuracy by:

$$4{\cdot}77 - 0{\cdot}04\,\mathrm{CN} - 0{\cdot}04\,\mathrm{CS} - 0{\cdot}05\,\mathrm{H}$$

Fig. 1. Average means of daily duration of bright sunshine for the year.

If the results obtained from this equation are compared with the true averages listed in M.O. 572 (Averages of Bright Sunshine for Great Britain and Northern Ireland) it is found that over half the stations give answers within 0·1 hours/day of the correct value, that is, within 6 minutes per day. Over 90 per cent of the stations lie within 0·3 hours/day of the correct answer, and the outstanding exceptions are those which lie in smoke-laden areas and have less sunshine than would be indicated by the formula. There are two areas where there is more sunshine than the formula suggests, these are the Welsh Marches and the extreme north-east of England.

This is illustrated in Fig. 2 below.

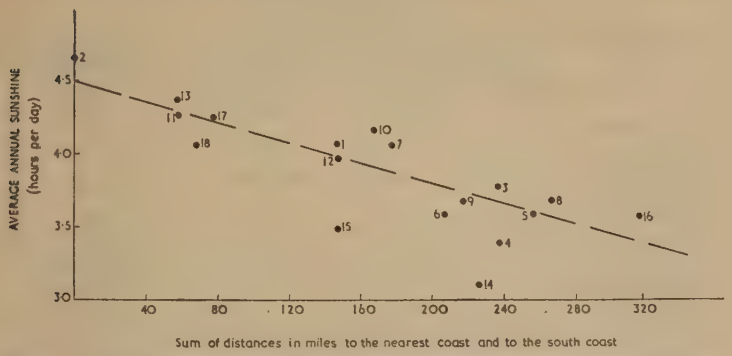

Fig. 2. True annual average sunshine plotted against CN and CS for the following stations:

1. Aberystwyth
2. Torquay
3. Scarborough
4. Sheffield
5. Stonyhurst
6. Birmingham
7. Cranwell
8. Harrogate
9. Leamington Spa
10. Malvern
11. East Malling
12. Ross-on-Wye
13. Porton
14. Buxton
15. Rhayader
16. Durham
17. Long Sutton
18. Bath

The two highest stations, Buxton and Rhayader, and the two smoky stations, Sheffield and Birmingham, show the biggest deviation from the straight line grouping. Fig. 3 shows the comparison between actual and calculated values when height has been allowed for in the triple regression. The striking feature here is the outstanding sunshine of Malvern which can be explained by the sheltering effect of the Welsh hills.

Similar equations can be found for each of the seasons, namely:

Winter Sunshine .	. 2·19 − 0·03 CN − 0·02 CS − 0·04 H
Spring Sunshine .	. 5·84 − 0·08 CN − 0·04 CS − 0·05 H
Summer Sunshine	. 7·14 − 0·06 CN − 0·06 CS − 0·04 H
Autumn Sunshine	. 3·82 − 0·04 CN—0·03 CS—0·04 H

These equations can be expressed in a less mathematical form as shown in Table 1 overleaf.

Most meteorological factors vary very considerably over small distances, but sunshine is one of the few which does not, and this empirical approach seems to give a close approximation to average annual and seasonal sunshine figures for anywhere in England and Wales, which is not subject to physical shading due to proximity to hills or buildings.

Table 1: Calculating Annual and Seasonal Sunshine

Basic Figure	Subtract from the basic figure:		
	for each 10 miles from nearest coast	for each 10 miles from south coast	for each 100 feet above sea level
	min	*min*	*min*
Annual sunshine 4 hr 45 min .	2½	2½	3
Winter sunshine 2 hr 11 min .	2	1	2½
Spring sunshine 5 hr 50 min .	5	2½	3
Summer sunshine 7 hr 8 min .	3½	3½	2½
Autumn sunshine 3 hr 49 min .	2½	2	2½

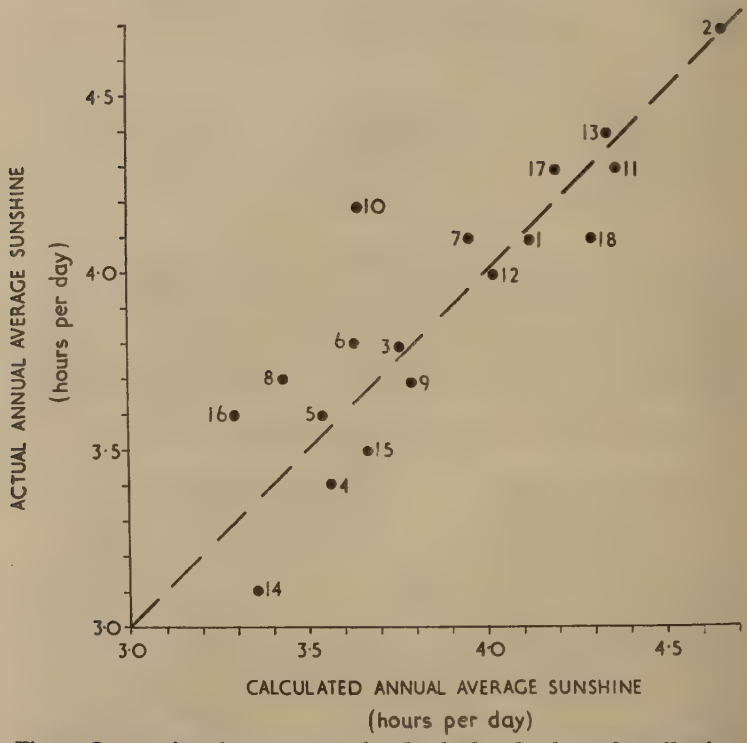

Fig. 3. Comparison between actual and calculated values after allowing for height.

Regional Note

An Exercise in Evaluation

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HOW MUCH of our advisory work is successful? How often is it producing results? Do we use the best methods to get our message over? Important as these questions are, few attempts have been made to try to answer them. Probably the main reason is the size and the difficulty of the problem. Due to the nature and scope of the advisory activities, and the complex and often obscure relation between cause and effect, evaluation is normally beyond the physical capacity of an individual officer, and may be difficult even with ample and up-to-date facilities.

However, it could probably be carried out more often where the "message" is clearly defined and the response relatively easy to measure, or to answer certain specific and fairly simple questions. A modest study in evaluation was undertaken in 1959 by the Department of Entomology, N.A.A.S. Eastern Region, and the object of this article is to show how this was done, some of the difficulties encountered and what results were obtained.

The Subject

In the spring of 1959, an article was published in *Agriculture*,* dealing with the control of pea moth, and explaining that in the past many growers sprayed too early, before moths appeared in the crop. It also stated that in 1959 the Department of Entomology would issue spray warnings based on the presence of moths and eggs on peas, and it invited the growers to avail themselves of this service through the D.A.O.'s, who were kept informed. Short notes appeared later in *The Farmers Weekly* and *The Farmer and Stock-Breeder* giving further publicity to the scheme. We wanted to know how many growers had seen the various press articles, and how many had been influenced by what they had read. This initial aim was expanded to take into account any advice which the grower might receive from the D.A.O.'s, or from other sources, and we also hoped to assess the effect of a concentrated attack on a small section of growers by a circular advisory letter signed by the C.A.O.

The main objects of the investigation were finally defined as follows:

1. to assess what proportion of growers received advice on the correct date of spraying;

* H. J. GOULD and T. J. LEGOWSKI. *Agric., Lond.*, 1959, **65**, 611–14.

2. to locate the source of that advice;
3. to determine in how many instances the advice had been followed;
4. to assess what proportion of pea growers read about our pea moth spray warning service.

Method

The investigation was carried out partly by a visit and an interview, and partly by a questionnaire.

Since, as in previous years, the Department was to survey some 100 fields of dry peas for pea moth damage, the opportunity was also taken to interview the owners. Questionnaires were also sent to nearly 270 growers, on the basis of a list compiled by the Ministry's Statistical Branch at Guildford, and drawn from three of the main pea-growing counties in the Eastern Region: Essex, Isle of Ely, and Lincs. (Holland).

The total sample, which was stratified according to the pea acreage per holding, represented nearly 15 per cent of the pea acreage grown in 1958 in these counties, and nearly 10 per cent of the number of holdings growing peas. At the start of the investigation, it comprised nearly 380 growers.

The investigation began on May 15th and finished towards the end of July. It had three main stages:

Firstly, a brief "invitation" letter was sent to 104 growers,* which explained the latest development in pea moth control and invited the grower to return an attached slip of paper if he wished to be notified when the time of spraying was due.

Secondly, a notification that it was time to spray was sent to those growers who had responded.

Thirdly, some growers were interviewed and the questionnaire sent to the remainder. The visit was preceded by a letter requesting permission to examine the fields and asking for certain details, e.g., sowing dates, variety, etc. Only those growers who replied were visited.

The same questions were addressed to all growers whether they were interviewed or sent a questionnaire. Questions were divided into two parts. Part 1 asked for details of pea fields and of any methods of control, while part 2 asked the following questions:

1. (*a*) Have you read a Press article this year about the best time to spray?
   (*b*) Where did you read it?
2. (*a*) Have you received any advice this year about the best time to spray?

* Approximately equally divided between the "Interview" group and the "Questionnaire" group.

(*b*) Who gave you the advice?
(*c*) Did you follow the advice?

3. If we can develop a warning system for pea growers advising them when to start spraying would you like to be included?

Results

RESPONSE

The gradual diminution of the original sample is a problem which can easily be underestimated and for which ample allowance should be made.

Thus, out of 104 pea growers who were sent the invitation, little over half replied. Usually, only about 30 per cent of the growers would be likely to spray, so the response was not unsatisfactory and "wastage" at this stage was anticipated. But when prior to a visit and interview a letter was sent requesting permission to inspect the fields, rather more than a third of the growers failed to reply. The response was only slightly better from those growers with whom contact had already been established via the "invitation" and who had requested and received the advice, compared with the remainder in the "Interview" group who had not been sent the "invitation". The questionnaire was even less successful, as out of nearly 270 growers to whom it was sent, almost two-thirds failed to reply. In every case the response was worse from growers with the smallest pea acreage.

Part of this wastage—perhaps as much as a third—was due to the fact that many growers were not growing peas in 1959. The remainder was probably caused by forgetfulness, lack of time and perhaps insufficient interest. Not all growers answered all questions, and some of the results given below are based on different numbers of replies.

PROPORTION OF GROWERS WHO RECEIVED ADVICE ON SPRAYING

The 150 growers who supplied answers on this topic can be considered under four groups:

1. *All growers who were not sent the advisory letter.* Thirty-six per cent said that they received advice from some source: 10 per cent from the N.A.A.S., 20 per cent from the spraying firms, 7 per cent from the canning firms and 7 per cent from other bodies. Obviously, some growers received advice from more than one source.

2. *All growers who were sent the advisory letter.* Seventy per cent said they received the advice and nearly 80 per cent of these named the N.A.A.S. and the rest other organizations as the source. This emphasizes the fact that errors are likely to arise where reliance is placed on memory. Nevertheless, it is clear that the majority of those growers who received the advice by letter were well aware of it, and a large proportion of them were also able to recall where this advice had come from. This supports

the view that the circular advisory letter can be a very useful tool—an opinion already held by many advisers in this Region.

3. *Those growers who sprayed and who were not sent the advisory letter.* About 70 per cent admitted receiving advice from some source: 20 per cent from the N.A.A.S., 5 per cent from a canning firm which received and passed on the advice from this department, 7 per cent from other canning firms, 27 per cent from chemical firms and 12 per cent from other sources.

4. *Those who sprayed and who were sent the advisory letter.* There were only 12 growers in this group, and 3 of them said that they had no advice. This again shows that allowance should be made for faults of memory.

Therefore, if one made a modest assumption that by the time this survey was carried out about 20 per cent of growers forgot whether they had in fact received any advice and where it came from, it would seem that some 80–90 per cent of those who sprayed received advice; of these, about 30 per cent had had it directly or indirectly from the N.A.A.S.; roughly the same proportion received it from the chemical firms and the rest from canners and other sources. Following the publicity given to the spray warning scheme, some of the chemical firms were in close contact with this department and received the up-to-date information on moth emergence and timing of spraying. The N.A.A.S. can, therefore, presumably claim some credit for part of their advice. Nearly all growers who were advised by the N.A.A.S. were in the group with the largest pea acreage, so the advice would have covered a much larger proportion of pea acreage than indicated by the percentage of growers advised.

HOW MANY GROWERS FOLLOWED THE ADVICE?

The replies were checked by referring to the date of spraying. Those growers who followed the N.A.A.S. advice would have sprayed after and not before the spray warning was sent out. Due to the early season and the advanced stage of growth which most of the dry peas had reached by the time the warning was sent out, the general tendency was to spray well before that date.

Most of the growers who sprayed and received advice from any source said that they had followed it. The answers of those who received direct or indirect advice from the N.A.A.S. showed that out of 19 growers, 17 sprayed at the right time and 2 at the wrong time. These 2 admitted that they followed the advice "partly". This confirms that most of the growers who acknowledged advice from the N.A.A.S. have in fact followed it. In contrast, out of 11 growers who had no advice from any source, 9 sprayed too early. Ninety-four per cent of the growers wanted to be included in the spray warning scheme in future.

HOW MANY GROWERS READ ABOUT THE CONTROL OF PEA MOTH?

Out of 140 growers who supplied the answers on this topic, 40 admitted reading about the control of pea moth: 10 could not remember where they read it, 12 pointed to leaflets and handbooks, 9 to farming weeklies, 2 to *Agriculture*, and 7 to a local paper which had published an article by a member of N.A.A.S. a few weeks before spraying. This supports the common belief that a local newspaper is one of the more effective advisory media. The figures furthur suggest that the direct —as opposed to the indirect—effect of the article in *Agriculture* and of the short notes in the farming weeklies could not have been very big.

Other Information

The survey has also given other information of value to the department. For example, we learned what proportion of growers sprayed against pea moth in 1959 and in the previous two years. The figures are given below:

Growers who Sprayed Against Pea Moth in 1959 and in 1957–58

	Essex		Isle of Ely		Lincs. (H)		Total 1959	Total 1957–58
	1959	1957–58	1959	1957–58	1959	1957–58		
Number of replies .	67	61	38	38	50	46	155	145
% sprayed .	35	49	43	50	22	18	33	40

There were comparatively few growers who sprayed in 1959 and not in the previous two years. It seems that there is quite a solid core of those who spray fairly regularly and of those who spray seldom or never.

Information has also been obtained on the proportion of growers who sprayed from the ground or from the air, and who employed contractors or did their own spraying. The figures are as follows:

Essex			Isle of Ely			Lincs. (Holland)			Total		
Ground		Air	Ground		Air	Ground		Air	Ground		Air
G.*	C.†		G.	C.		G.	C.		G.	C.	
16	4	4	13	2	2	6	0	5	35	6	11

* G. = Grower. † C. = Contractor.

Just over 80 per cent of growers used DDT, about 10 per cent used parathion, and the remainder other materials. Although two spray applications are usually recommended, only 6 growers out of 52 sprayed the crop more than once.

Conclusions

The investigation helped to answer several questions. The results show that at least 70 per cent of the growers who sprayed received some advice on spraying, and that about 30 per cent of them received it from the N.A.A.S. and approximately 50 per cent from chemical and canning firms. On an acreage basis, the share of the N.A.A.S. would probably be nearer 50 per cent. That some of the chemical and canning firms requested and were given information by the N.A.A.S. should also be taken into account. It appears that in most instances where advice was accepted it had been followed, and that the circular advisory letter signed by the C.A.O. was a very successful means of conveying this advice. Some of the counties in this Region are already making quite considerable use of circular advisory letters in their work. The effect of the article in *Agriculture*—mainly indirect—was quite important. It brought the spray warning service to the attention of some of the spraying and canning firms, which was valuable in view of their share of the contacts with the grower. The investigation has shown that quite a large proportion of growers and of the sprayed acreage has not been reached by the N.A.A.S. In future, approach through the outside firms coupled with a more extensive use of the advisory letter would probably offer the best solution. In addition, the investigation has supplied much technical information which has already proved very useful to this department. It has also given us further experience in evaluation which we and perhaps others may find helpful in future.

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